Food Spoilage

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What is Food ?

- Food is any substance consumed to provide nutritional support for an organism. It is usually of plant or animal origin, and contains essential nutrients, such as carbohydrates, fats, proteins, vitamins, or minerals.

- The substance is ingested by an organism and assimilated by the organism's cells to provide energy, maintain life, or stimulate growth.

Types of Food

On the basis of susceptibility of spoilage, foods can be grouped as:

1. **Perishable** which spoil quickly within few days. They must be kept refrigerated or frozen, perishable foods include dairy products, meat, poultry, fish.
2. **Semiperishable** have relatively long shelf life; few weeks or months. e.g. bread, butter, cake , many canned fruits.
3. **Nonperishable** having very long shelf life for months or years e.g. canned fruits and vegetables, dried fruits and vegetables, peanut butter.

Food Spoilage

- A food is considered spoiled when it loses its acceptance qualities. The factors considered in judging the acceptance qualities of a food include color, texture, flavor (smell and taste), shape and absence of abnormalities. Loss of one or more normal characteristics in a food is considered to be due to spoilage.
- Food spoilage causes not only economic loss, but also loss of consumable foods.

Food Spoilage

- Spoilage is the process in which food deteriorates to the point in which it is not edible to humans or its quality of edibility becomes reduced. Various external forces are responsible for the spoilage of food. Food that is capable of spoiling is referred to as perishable food.
- Food spoilage means the original nutritional value, texture, flavour of the food are damaged, the food become harmful to people and unsuitable to eat.
- Food spoilage can be defined as a disagreeable change in a food's normal state. Such changes can be detected by smell, taste, touch, or sight. These changes are due to a number of reasons - air and oxygen, moisture, light, microbial growth and temperature.

Causes of Food Spoilage

The major causes of food spoilage include:

1. Microorganisms, their growth and activity
2. Action of native enzymes
3. Insects, rodents, parasites and other creatures
4. Chemical reactions of the constituents of food
5. Environmental factors such as air and oxygen moisture, light & temperature
6. Physical Damage
7. Time

Microbial Spoilage

- Microbial food spoilage occurs as a consequence of either microbial growth in a food or release of microbial extracellular and intracellular enzymes in the food environment. Some of the detectable parameters associated with spoilage of different types of foods are changes in color, odor and texture; formation of slime; accumulation of gas (or foam); and accumulation of liquid (exudate, purge).

Microbial Spoilage

- Microorganisms such as molds, yeasts and bacteria can grow in food and cause spoilage. Bacteria also can cause foodborne illness. Viruses and parasites, such as tapeworms, roundworms and protozoa, can cause foodborne illness, but they are not capable of growing in food and do not cause spoilage.

Microbial Spoilage of Foods

Significance of Microorganisms

A. Microbial Types

- Raw and most processed foods normally contain many types of molds, yeasts and bacteria capable of multiplying and causing spoilage. Viruses do not multiply in foods.
- As multiplication is an important component in spoilage, bacteria (because of shorter generation time), followed by yeasts, are in favorable positions over molds to cause rapid spoilage of foods.

Significance of Microorganisms

B. Microbial Numbers

- Microorganisms must multiply to certain levels in order to be able to cause food spoilage. This is referred to as spoilage detection level.
- The spoilage detection level can range from 10(6)-10(8) cells/g, ml, or cm(2).
- Spoilage associated with H_2S, some amines and H_2O_2 formation can be detected at a lower microbial load, where as formation of lactic acid may be detected at higher microbial load.

Significance of Microorganisms

- Higher initial loads of spoilage bacteria or yeasts and a storage conditions that favours rapid growth will cause the food to spoil more rapidly.

- Food with low initial microorganisms load and stored at 4°C, the generation time will be longer, spoilage will take more time to occur and food could be stored for long time.

Significance of Microorganisms

C. Predominant Microorganisms

- The microbiological profile of a food is quite different from that of a pure culture growing in a laboratory medium.
- An unspoiled, nonsterile food generally contains many types of microorganisms, such as bacteria, yeasts and molds (also viruses) from different genera, maybe more than one species from the same genus and even more than one strain from the same species. The population level of each type can vary greatly.
- However, when the same food is spoiled, it is found to contain predominantly one or two types.

Bacteria

- Bacteria can be responsible for the spoilage of food. When bacteria breaks down the food, acids and other waste products are created in the process. While the bacteria itself may or may not be harmful, the waste products may be unpleasant to taste or may even be harmful to one's health.
- Bacteria are the most important and troublesome of all the microorganisms for the food processor.
- The bacterial pathogens that are most likely to be found in livestock and poultry include *Salmonella*, *Campylobacter, and L. monocytogenes.*
- *L. monocytogenes* also is widespread in the environment. *E. coli* also are found in livestock and poultry, but most strains are not pathogenic. The pathogenic *E. coli* of primary concern is known as *E. coli* O157:H7 and is found in beef.

- Some bacteria, such as *C. perfringens* and *C. botulinum*, also can be found in meat and poultry, forming spores that may survive cooking and increase in numbers in foods due to temperature abuse, though *C. botulinum* may be found in far fewer numbers than *C. perfringens.*
- *B. cereus* is another spore former of concern in meat and poultry products, especially products containing dry ingredients or spices, which are a common source of the spores.
- The U.S. Centers for Disease Control and Prevention (CDC) reports that the most common foodborne illnesses for which an organism has been identified are those caused by the bacteria *Campylobacter, Salmonella*, *L. monocytogenes*, and *E. coli* O157:H7 and the norovirus.

Bacterial Spoilage

Some Important Food Spoilage Bacteria

- Theoretically, any microorganism that can multiply in a food to reach a high level (spoilage detection level) is capable of causing it to spoil.
- Yet, in reality, bacterial species from only several genera have been implicated more with spoilage of most foods. This is dictated by the bacterial characteristics, food characteristics and the storage conditions.

Some Important Food Spoilage Bacteria

A. Psychrotrophic Bacteria

- Psychrotrophic bacteria constitute the bacterial species capable of growing at 5ºC and below, but multiply quite rapidly at 10 to 25°C and even at higher temperatures.
- Psychrotrophic bacteria (also many yeasts and molds that are psychrotrophic) can cause spoilage in foods. If the food is stored under aerobic conditions, psychrotrophic aerobes are the predominant spoilage bacteria.
- In foods stored under anaerobic conditions, anaerobic and facultative anaerobic bacteria predominate.

Some Important Food Spoilage Bacteria

1. Some Important Psychrotrophic Aerobic Spoilage Bacteria

They include *Pseudomonas fluorescens*, *Pse. fragi*, other *Pseudomonas species*, *Acinetobacter*, *Moraxella*, and *Flavobacterium.*

2. Some Important Psychrotrophic Facultative Anaerobic Spoilage Bacteria

They include *Brochothrix thermosphacta*, *Lactobacillus viridescens*, *Lab. sake*, *Lab. curvatus*, unidentified *Lactobacillus spp.*, *Leuconostoc carnosum*, *Leu. gelidum*, *Leu. mesenteroides*, *unidentified Leuconostoc spp.*, some *Enterococcus spp.*, *Alcaligenes spp.*, *Enterobacter spp.*, *Serratia liquifaciens*, *some Hafnia and Proteus spp.*, and *Shewanella putrefaciens* (and some microaerophilic yeasts).

Some Important Food Spoilage Bacteria

3. Some Important Thermoduric Psychrotrophs

They include facultative anaerobes, such as spores of *Bacillus coagulans* and *B. megaterium*, some strains of *Lab. viridescens*; and anaerobes, such as spores of *Clostridium laramie*, *C. estertheticum*, *C. algidicarnis*, *C. putrefaciens*, and unidentified *Clostridium spp*. The spores survive low-heat treatment. Following germination and outgrowth, the cells grow at low temperature.

When a food is temperature abused above 5°C (such as during transport or display in stores), some true mesophiles (growth temperature range 15 to 45°C, optimum 25 to 40ºC) can also grow. However, at 10 to 15°C, psychrotrophs will generally grow much faster than these mesophiles.

Some Important Food Spoilage Bacteria

B. Thermophilic Bacteria

The bacteria in this group grow between 40 and 90°C, with optimum growth at 55 to 65°C.

Spores of some thermophilic *Bacillus* and *Clostridium spp*. can be present in these heat-treated foods, which at warm temperature germinate and multiply to cause spoilage.

Some Important Food Spoilage Bacteria

C. Aciduric Bacteria

Bacteria that can grow relatively rapidly in food at pH 4.6 or below are generally regarded as aciduric (or acidophilic).

They are usually associated with spoilage of acidic food products such as fruit juices, pickles, salsa, salad dressings, mayonnaise and fermented sausages.

Molds

- A mold is a fungus that grows in the form of multicellular filaments called hyphae. In contrast, fungi that can adopt a single-celled growth habit are called yeasts. There are thousands of known species of molds.
- Molds are larger than bacteria or yeast and members of the fungi family. They are multiple cell organisms forming tubular filaments. Molds demonstrate branching and reproduce by means of fruiting bodies, called spores, which are borne in or on aerial structures.

Molds

- Molds are widely distributed in nature, both in the soil and in the dust carried by air. Under suitable conditions of moisture, air and temperature, molds will grow on almost any food. The black or green discoloration that appears on moldy bread is familiar evidence of such growth.
- Molds cause biodegradation of natural materials, which can be unwanted when it becomes food spoilage.

Spoilage by Molds

Molds

- Aflatoxins are toxins produced by molds. Aflatoxins can cause liver damage and cancer in human.
- Molds are capable of consuming acids, thereby raising the pH of products & the product becomes further susceptible to bacterial growth.
- On very rare occasions, their growth in foods has removed the acid conditions that inhibit the growth of *C. botulinum*.
- Most molds have little heat resistance and cannot survive the thermal processes for low-acid canned foods.

- Therefore, molds are present in canned meat and poultry products only as a result of gross under-processing or as a post-processing contaminant. Since molds must have oxygen to grow, only slight growth can occur, unless the food container has an opening to the outside environment.

Some Important Food Spoilage Molds :

- *Alternaria*
- *Aspergillus*
- *Cladosporium*
- *Geotrichum*
- *Monilia*
- *Mucor*
- *Penicillium*
- *Rhizopus*
- *Sporotrichum*

Yeasts

- Yeasts are eukaryotic, single-celled microorganisms classified as members of the fungus kingdom and 1,500 species are currently identified.
- Active in warm, moist conditions with food for growth.
- Yeasts can grow without oxygen (anaerobic growth)
- Responsible for food spoilage in high sugar foods such as fruit jam and yoghurts.

Yeasts

- Yeasts can be responsible for the decomposition/spoilage of food with a high sugar content. The same effect is useful in the production of various types of food and beverages, such as bread, yogurt, cider and alcoholic beverages.

- Yeasts are widely found in nature and are particularly associated with liquid foods containing sugars and acids. They are quite adaptive to adverse conditions such as acidity and dehydration. Like molds, yeasts are more tolerant to cold than to heat.

- In canned food, the presence and growth of yeast may result in spoilage, generally in the form of alcohol production and large amounts of carbon dioxide gas, which swells the container.
- Raw materials and ingredients are the primary source of food contamination.
- **Some Important Food Spoilage Yeasts :**
- *Candida*
- *Cryptococcus*
- *Debaryomyces*
- *Pichia*
- *Rhodotorula*
- *Saccharomyces*
- *Torulopsis*
- *Trichosporon*

Spoilage by Yeasts

Intrinsic and Extrinsic Parameters of Foods that Affect Microbial Growth

Intrinsic Parameters

The parameters of plant and animal tissues that are an inherent part of the tissues are referred to as intrinsic parameter. These parameters are as follows:

1. pH
2. Moisture content
3. Oxidation–reduction potential (Eh)
4. Nutrient content
5. Antimicrobial constituents
6. Biological structures

Intrinsic Parameters

pH Effects

- Adverse pH affects at least two aspects of a respiring microbial cell: the functioning of its enzymes and the transport of nutrients into the cell.
- The cytoplasmic membrane of microorganisms is relatively impermeable to H^+ and OH^- ions.

Intrinsic Parameters

Moisture Content

- One of the oldest methods of preserving foods is drying.
- The preservation of foods by drying is a direct consequence of removal or binding of moisture, without which microorganisms do not grow.
- It is now generally accepted that the water requirements of microorganisms should be described in terms of the water activity (a_w) in the environment.

Intrinsic Parameters

Effects of Water Activity (a_w)

- The general effect of lowering a_w below optimum is to increase the length of the lag phase of growth and to decrease the growth rate and size of final population. This effect may be expected to result from adverse influences of lowered water on all metabolic activities because all chemical reactions of cells require an aqueous environment.
- It must be kept in mind, however, that a_w is influenced by other environmental parameters such as pH, temperature and Eh.

Intrinsic Parameters

Oxidation–Reduction Potential (Eh)

- Oxidation is the loss of electrons or an increase in oxidation state by a molecule, atom, or ion.
- Reduction is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion.
- It has been known for decades that microorganisms display varying degrees of sensitivity to the oxidation–reduction potential (O/R, Eh) of their growth medium.

Intrinsic Parameters

Eh Effects

- Microorganisms affect the Eh of their environments during growth just as they do pH. The Eh of a medium can be reduced by microorganisms by their production of certain metabolic byproducts such as H_2S.

Intrinsic Parameters

Nutrient Content

In order to grow and function normally, the microorganisms of importance in foods require the following:

1. Water
2. Source of energy
3. Source of nitrogen
4. Vitamins and related growth factors
5. Minerals

Intrinsic Parameters

Antimicrobial Constituents

- The stability of some foods against attack by microorganisms is due to the presence of certain naturally occurring substances that possess and express antimicrobial activity.
- Some plant species are known to contain essential oils that possess antimicrobial activity. Among these are eugenol in cloves, allicin in garlic, cinnamic aldehyde and eugenol in cinnamon, allyl isothiocyanate in mustard, eugenol and thymol in sage and carvacrol (isothymol) and thymol in oregano.

Intrinsic Parameters

Antimicrobial Constituents

- Cow's milk contains several antimicrobial substances, including lactoferrin, conglutinin, and the lactoperoxidase system. It is destroyed by pasteurization. Milk casein as well as some free fatty acids have been shown to be antimicrobial under certain conditions.
- Eggs contain lysozyme, as does milk, and this enzyme, along with conalbumin, provides fresh eggs with a fairly efficient antimicrobial system.

Intrinsic Parameters

Biological Structures

- The natural covering of some foods provides excellent protection against the entry and subsequent damage by spoilage organisms. In this category are such structures as the testa of seeds, the outer covering of fruits, the shell of nuts, the skin of animals and the shells of eggs.
- In the case of nuts such as pecans and walnuts, the shell or covering is sufficient to prevent the entry of all organisms.

Extrinsic Parameters

The extrinsic parameters of foods are not substrate dependent. They are those properties of the storage environment that affect both the foods and their microorganisms. Those of greatest importance to the welfare of foodborne organisms are as follows:

1. Temperature
2. Relative humidity of environment
3. Presence and concentration of gases
4. Presence and activities of other microorganisms

Extrinsic Parameters

Temperature

- Microorganisms, individually and as a group, grow over a very wide range of temperatures. Therefore, it is well to consider at this point the temperature growth ranges for organisms of importance in foods as an aid in selecting the proper temperature for the storage of different types of foods.
- The lowest temperature at which a microorganism has been reported to grow is −34◦C; the highest is somewhere in excess of 100◦C. It is customary to place microorganisms into three groups based on their temperature requirements for growth.

Extrinsic Parameters

Relative Humidity of Environment

- The RH of the storage environment is important both from the standpoint of a_w within foods and the growth of microorganisms at the surfaces.

Extrinsic Parameters

Presence and Concentration of Gases in the Environment

- Carbon dioxide (CO_2) is the single most important atmospheric gas that is used to control microorganisms in foods. It along with O_2 are the two most important gases in modified atmosphere packaged foods.
- Ozone (O_3) is the other atmospheric gas that has antimicrobial properties, and it has been tried over a number of decades as an agent to extend the shelf life of certain foods.
- It has been shown to be effective against a variety of microorganisms, but because it is a strong oxidizing agent, it should not be used on high-lipid-content foods since it would cause an increase in rancidity.
- Ozone was tested against *Escherichia coli* 0157:H7 in culture media, and at 3 to 18 ppm the bacterium was destroyed in 20 to 50 minutes.

Extrinsic Parameters

Presence and Activities of other Microorganisms

Some foodborne organisms produce substances that are either inhibitory or lethal to others; these include antibiotics, bacteriocins, hydrogen peroxide and organic acids. The inhibitory effect of some members of the food biota on others is well established.

Chemical Spoilage

Concerning the chemical composition of foods, it may be noted that carbohydrates, particularly sugars, are preferred by microorganisms as energy sources and only a few kinds of microorganisms can obtain energy from fats.

Chemical Spoilage

Three factors in chemical changes or rancidity of lipids:

1. **Lipid Autolysis:** enzymatic hydrolysis with fatty acids and glycerol as main product.
2. **Auto-oxidation:** the reaction of unsaturated lipid with oxygen. Oxidative rancidity in fish can result to serious quality problems such as rancid flavors and odors as well as discoloration.
3. **Denaturation** of proteins during frozen storage resulting to tough, dry and fibrous texture.

- The most common chemical action which causes spoilage is the oxidative rancidity in fatty fishes.
- Fish is characterized by a high level of polyunsaturated fatty acids and hence under goes oxidative changes.

Chemical Spoilage

- Chemical changes begin automatically after fruits and vegetables are harvested, or animals are killed (slaughtered).
- Oxygen in air, sunlight and high temperature can cause certain foods to undergo undesirable chemical changes.
- Chemical changes affect the color and flavor of foods- fats and pigments in food are mainly affected, e.g. unpleasant smell and taste of cooking oil after use at high temperature.

Autolytic Spoilage

- Autolytic spoilage caused by enzymes.
- After the death, the normal circulatory system breaks down and chemical signals leak into the muscle causing them to stiffen. This process is known as **Rigor Mortis**.
- The blood circulation stop and the supply of oxygen is prevented. The enzymes present in muscle convert glycogen into lactic acid. The pH of the fish muscle falls.
- After the composition of rigor mortis, muscle stiffness gradually decreases accompanied by increases in pH, ending up in softening of muscle. This is followed by breakdown of proteins by enzymes. This process is called as autolysis.
- Autolysis of protein starts immediately after rigor and favourable conditions for the growth of bacteria.

Autolytic Spoilage

- Every living organism uses specialised proteins called enzymes to drive the chemical reactions in its cells.
- After death, enzymes play a role in the decomposition of once living tissue, in a process called autolysis (self-destruction) or enzymatic/autolytic spoilage.
- For example, some enzymes in a tomato help it to ripen, but other enzymes cause it to decay.
- Once enzymatic spoilage is under way, it produces damage to the tomato skin, so moulds can begin to can attack it as well, speeding the process of decay.

Autolytic Spoilage

Autolytic Spoilage

- When fruits or vegetables are peeled or cut, the plant tissue releases some enzymes which in the presence of oxygen from the air, chemically react with plant compounds to give brown pigments e.g. apples, banana, guava etc. This reaction is known as enzymatic browning.
- The red pigment in meat undergoes chemical changes and turns brown when it is exposed to oxygen.
- Enzymes cause food to ripen, then become over-ripe and eventually decay. Starch changes to sugar, color changes and texture softens.
- Enzymes in fish cause deterioration even at low temperatures.


Thank You